Acoustic Scattering by Shell-Covered Seafloors

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LONG-TERM GOALS

To understand the acoustic reverberation properties of the seafloor when benthic shells are present. Quantitative characterization of these properties will lead to improved capability in predicting sonar performance and use of sonars in the mapping of benthic shells.

OBJECTIVES

To understand the physics of acoustic scattering by benthic shells. Realistic acoustic scattering models of various important classes of these complex scatterers will be developed and applied to at-sea experiments and surveys involving high frequency acoustic sonars.

APPROACH

Benthic shells are in the broad acoustic category of complex finite-sized shapes for which there is no exact mathematical solution to describe the acoustic scattering. Subsequently, the research program is a combination of theoretical analysis, numerical simulations, laboratory experimentation at WHOI, and comparison between models developed in this program and scattering data collected at sea. A crucial aspect of describing the scattering requires understanding the precise shape of the target. Measurements of the shape are made through use of medical computerized tomography using the WHOI CT facility. The theoretical analysis involves taking into account scattering by the surface of the shells as well as sharp edges, which may, under some conditions, dominate the scattering. The

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14. ABSTRACT

To understand the acoustic reverberation properties of the seafloor when benthic shells are present. Quantitative characterization of these properties will lead to improved capability in predicting sonar performance and use of sonars in the mapping of benthic shells.

15. SUBJECT TERMS

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laboratory experiments are principally in the backscatter configuration, although some forward scattering measurements are made. The measurements are in the 40-95 kHz frequency range using a broadband chirp signal. A computer-controlled stepper motor is used to rotate the shells so that the scattering can be measured over all angles of orientation (in one plane) in one-degree increments. Both spectral and time domain (through pulse compression) analyses are conducted. The models are to be initially compared with the laboratory data for refinement, and then incorporated into a generalized seafloor scattering model for comparison with data collected at sea. The ocean data are from the ONR SAX99 experiment off the west coast of Florida, as well as from an experiment within this program involving sand dollars near Humboldt Bay, California. The shells used in the laboratory measurements (and associated CT scans) are the same as those used in the SAX99 experiment and similar to those surveyed near Humboldt Bay. Tim Stanton oversees the entire program, and is leading the laboratory experiments and model development of the scattering by individual shells. Greg Crawford is conducting the field experiment near Humboldt Bay and Anatoliy Ivakin will be incorporating the shell scattering models into his generalized seafloor scattering model. All three PI's will be involved in comparing the models with the at-sea measurements. Also, Dezhang Chu (WHOI) plays a key role in the laboratory and modeling work and Andone Lavery (WHOI) oversees the CT scans.

WORK COMPLETED

Three major tasks were completed in this second year of the grant. The tasks were principally focused on experimentation and data analysis. One paper was submitted to a refereed journal.

<u>1) Laboratory experiments</u>. Measurements of acoustic backscattering and forward scattering of various shells and metal disks were made in a flume tank at WHOI during the fall of 2002. Most measurements involved single targets although some involved an aggregation of bivalves. The following targets were used: bivalves, mostly from the SAX99 experiment; one sanddollar from the Humboldt Bay area; and metal disks of various diameters (2-20 cm) and thicknesses (0.6-1.9 mm), all but one disk were composed of aluminum and the remaining one of stainless steel. All measurements involved use of a broadband chirp signal, 40-95 kHz, and varying the orientation of the target(s) over 360 deg. of rotation in one plane and in one-deg. increments. The majority of measurements were in the backscatter direction. The forward scatter measurements involved two disks (individually), the sanddollar, and one aggregation of 24 bivalves (from the SAX99 experiment) in two different random configurations.

<u>2) Data analysis and comparison with two ocean experiments</u>. Extensive processing was performed on the laboratory data. The data, once calibrated, has been displayed in terms of total (i.e., using entire waveform) target strength and partial (i.e., using part of waveform) versus frequency at fixed angle and versus angle at fixed frequency, color contours of those quantities, time series of compressed pulse output at fixed angles and color contours of compressed pulse output versus angle (Figs. 1-3).

The target strength values were used in comparison with previously published acoustic scattering data from two ocean experiments involving a shell-covered seafloor. One, from Jackson et al. (1986), where the variation in area scattering strength from normal incidence to shallow grazing angles was compared with the variation in target strength versus angle data. The other involved using the target strength of a bivalve (from the SAX99 experiment) to estimate area scattering coefficient at the angle corresponding with that in the SAX99 experiment.

<u>3) Field experiments</u>. Two cruises were conducted during the summer of 2003 near the entrance to Humboldt Bay in which sanddollars were observed both with acoustic backscatter and with a video camera. Grab samples were made as well. The backscattering measurements were made using a 120 kHz pencil-beam scientific echosounder at normal incidence and at a 55-deg. grazing angle. The transects were conducted in directions along the length of the bands of sanddollars, across the length, as well as outside the band. The video provided information on orientation of the sanddollars relative to the plane of the seafloor and relative to the direction of flow of water as well as their numerical density. Also, the presence of other species of benthic organisms (most notably crabs) was recorded.

RESULTS

A striking result from this year's research is the observation of strong diffracted echoes from the edge of the benthic shells. This is most apparent in the comparison between the scattering data from the disk (Fig. 1) in which edge-diffracted waves are expected and the sanddollar (Fig. 2) in which edge-diffracted waves were also observed and produced a scattering pattern similar to that of the disk. Edge-diffracted waves were also observed with the bivalve (Fig. 3), but over a narrower range of orientations. When comparing the scattering results from the edge-diffraction-dominated angles with data from the two ocean experiments involving shell-covered seafloors, there was reasonable agreement. These favorable comparisons suggest that the edges of the shells can play a major role in acoustic scattering by a shell-covered seafloor.

IMPACT/APPLICATIONS

The potential for impact and application of the results of this project is significant. Shells are potentially significant sources of scattering (and associated attenuation) of sound, especially when occurring in dense layers. The observed strength of the edge-diffracted echo suggests that this scattering mechanism needs to be taken into account in modeling of acoustic scattering by a shell-covered seafloor. Furthermore, since the edge of the shell plays such a role in the diffraction of sound, the results also suggest that sub-bottom targets can be detected at sub-critical angles when shells are present.

RELATED PROJECTS

This project is related to four other projects or programs: 1) Acoustic scattering classification by zooplankton and microstructure (funded by another grant by ONR), 2) Measurements and modeling of acoustic scattering by fish (funded by another grant by ONR and NOAA), 3) ONR SAX99 experiment in Gulf of Mexico, and 4) ONR SAX04 experiment planned for the Gulf of Mexico. This project takes advantage of the hardware and methodologies developed principally in (1) above and to some extent in (2), is currently applying the new results to data collected in (3) and is currently using the new results in the planning of (4).

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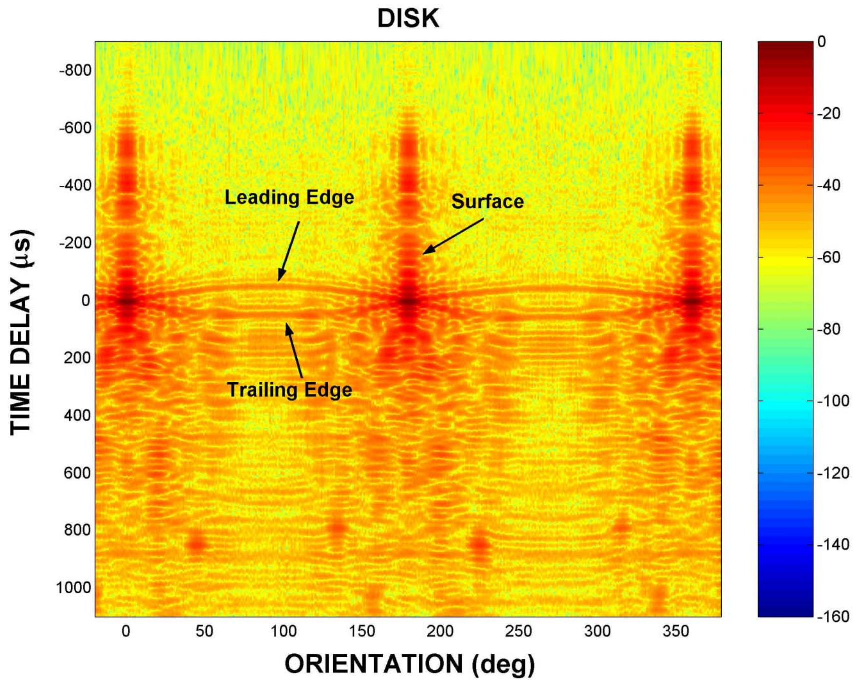
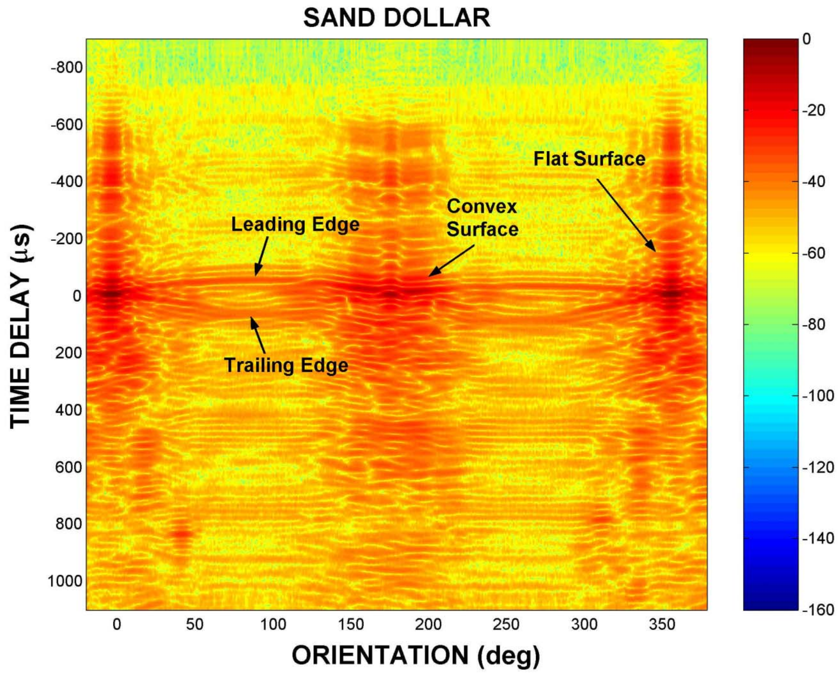
PUBLICATIONS

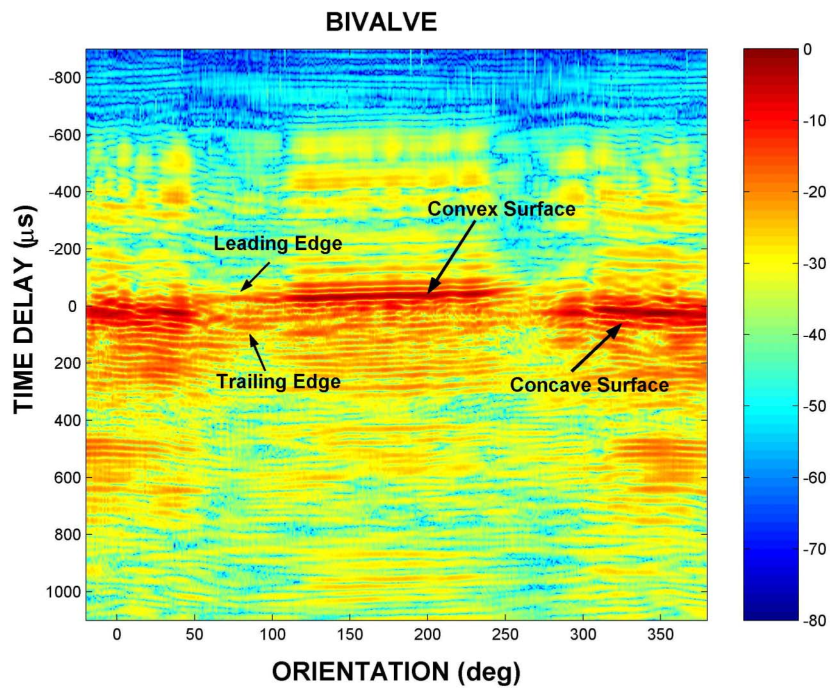
Stanton, T.K. and Chu, D. (submitted, refereed). "On the acoustic diffraction by the edges of benthic shells," J. Acoust. Soc. Am.



1. Color contour of compressed pulse output (dB) of acoustic backscattering versus orientation angle and time of return by 8-cm-diameter aluminum disk. Acoustic diffraction from leading and trailing edges of disk is illustrated.



2. Color contour of compressed pulse output (dB) of acoustic backscattering versus orientation angle and time of return by sanddollar (from near Humboldt Bay). Acoustic diffraction from leading and trailing edges of shell is illustrated.



3. Color contour of compressed pulse output (dB) of acoustic backscattering versus orientation angle and time of return by bivalve (from SAX99 experiment). Acoustic diffraction from leading and trailing edges of shell is illustrated.